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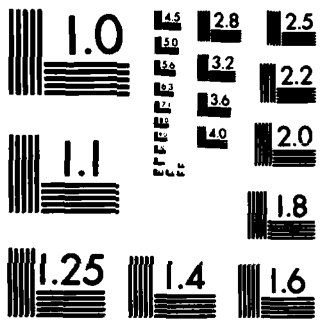

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ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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AGARD ADVISORY REPORT No.204

Technical Evaluation Report on the Avionics Panel Symposium on Design for Tactical Avionics Maintainability

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ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

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AGARD Advisory Report No.204

Technical Evaluation Report

on the

Avionics Panel Symposium

on

DESIGN FOR TACTICAL AVIONICS MAINTAINABILITY

Edited by

B.L.Dove and J.B.Clary

This publication was prepared at the request of the Avionics Panel of AGARD.

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TECHNICAL EVALUATION REPORT

by

Billy L.Dove and James B.Clary
Technical Program Co-Chairmen

EXECUTIVE SUMMARY
OBJECTIVES

The inherent logical makeup of digital systems presents the opportunity for improving the maintainability of complex avionic systems. While there was limited success in the early use of Built-In-Self-Test and Built-In-Test (BIST/BIT), higher levels of circuit integration now offer even greater opportunities and challenges to avionic systems designers. However, while past and current digital systems designs have BIST/BIT as an add-on feature, future avionic system designs must be designed for maintainability. Recently, improved techniques and tools to support design for maintainability have become available to avionics systems designers. If used appropriately, these new approaches can lead to dramatic improvements in avionic systems maintainability.

The objective of this symposium was to present, for review and discussion, advanced methods and tools to support design for avionic maintainability. Since modern avionic systems consist of programmable processors, both hardware and software design for maintainability issues and approaches were discussed. Originator-supplied key words include: → to p. 6

GENERAL

The symposium was held May 7—10 in Brussels, Belgium.

Approximately 105 people were registered.

Twenty-five papers were presented. In addition, there was a round table discussion, a technical tour of a new Bell Telephone Facility for fabricating hybrid and integrated circuits in Ghent and a tour of the Belgian Air Force Test Facility in Brussels.

CONCLUSIONS

- There is a need for improved communications between avionic systems users and developers.
- Design for maintainability concepts and technology to implement them exist but need further work.
- Both hardware and software design for maintainability are important in avionic systems.
- The "false alarm" problem with BIST/BIT is a significant problem in avionics maintenance today.
- Future avionic systems are being designed that use artificial intelligence approaches, including ones for the Mirage 2000 and the F-18.

TECHNICAL SESSIONS

The meeting was organized to present the views of both the users and the developers of tactical avionics. Both hardware and software were discussed. There were five sessions, defined as follows:

Session I Experience with Avionics Hardware Maintainability
Session II Avionics Hardware Design for Testability
Session III Experience with Avionics Software Maintainability
Session IV Avionics Software Design for Testability
Session V Future Avionics Maintainability Through Hardware/Software Co-Design

OPENING SESSION

0. *Keynote Address*
Colonel F.Kennis

In the 1950s, maintenance was easy. There were lots of planes, spare parts and maintenance personnel. But as the complexity increased, it became expensive to keep spares and skilled personnel. Today, there are new problems, including not being able to duplicate errors and not finding faults in the shop because the test tolerances are not the same as on the aircraft. In the future, there should be better organization between groups, both in design and maintenance. The software should be more modular and better documented. The BIT should be correct with easy replacement of failed modules and there should be better integration of maintenance.

1. *Objectifs d'Etude de la Maintenabilité des Systèmes Avionnés*
B.Courtois

Maintenance on the Mirage III, F1, and 2000 were compared. The 2000 has a centrally managed data bus for both on- and off-line functional testing. For second line maintenance, there is all purpose ATE with specific test benches. The problems include lengthy software tests, little use of information from the plane, ambiguities in the fault location, and too many specialized test benches. To reduce maintenance costs, it is recommended that external test equipment be reduced, time spent for fault detection and isolation reduced, false removals be minimized, and the number of mechanics needed should be cut. There should be a global maintenance policy, including a technical definition, integrated self tests, and artificial intelligence.

2. *Joint Service Design for Testability Program*
W.L.Keiner

The Joint Logistics Commanders (JLC) have established a program to coordinate development of testing technology and its management within the military services. In the area of testability, they have programs for testability program standards, testability analysis handbook, electronic testability guide, built-in test guide, and a design for testability (DFT) course. In DFT, they are looking at enhanced partitioning, increased test control, increased test access, improved BIT, and decreased costs. They are directing research in testability techniques and measures.

Session I — Experience with Avionics Hardware Maintainability
J.M.B.G.Mascarenhas, Chairman

3. *Test Intégré (BIT): Impact sur le Coût Global de Possession*
M.Kervella

The built-in test is important for aircraft and can be incorporated into the test strategy for multilevel testing. One wants to locate the faults as quickly as possible with personnel who have knowledge of the tests, but not the system. BIT has been included in recent Mirage aircraft. From the F1C to the 2000, they have experienced a decrease in reliability, a decrease in the length of test times, no ATE for first line maintenance, lower removal rates (from 30% to 20%), decrease in procurement costs for first line testing, and an increase in operation cost for first line testing.

4. *Study and Realisation of a Third Level Maintenance Center Based on ATE Systems Utilisation*
F.Bozzola

The development of a third level maintenance center based on ATE was discussed. They analyzed the problem, specifying both the hardware and the software needed prior to acquiring a system. This system, based on computers rather than specific ATE, is flexible and expandable by adding additional hardware. To train personnel, they have short course modules. They expect 80—90% fault coverage from programs which take 320—640 man-hours to develop, including documentation. They see a need for bare boards, removable coatings, bus accessibility, using connectors not wires, bringing test points out to a connector, accessible initialization points set/reset accessibility, normalized pin arrays, and updated configuration and management information.

5. *A Practical Example of Reducing Life Cycle Costs and Increasing Availability*
R.P.F.Lauder

Reliable components are only ten per cent of the reliability picture. The rest must be grown through testing. Mr Lauder feels the military could use many commercial (cheaper) components. Reliable connections are one of the biggest problems. One must reduce mean down time to increase availability. An example was given of improvements made on an existing radar system to increase availability.

7. *ATE User's View on Design for Maintainability*
J.M.B.G.Mascarenhas

Portugal has set up a test facility with ATE and advanced software. They have developed a TPA — test package adapter; one TPA per unit under test. Suggestions for DFT include having an ATE engineer on the design team, a standard ATE description language, the ability to stop the free running of a circuit, an interruptable feedback loop, test point

accessibility through the connectors, complete and clear definition of the initial state which is not time dependent, use of sockets, including BIT, big memories and proms with test patterns on boards.

8. *Experience of One UK Electronic Equipment Supplier with BITE on Engine Flight Control Systems over the Past Ten Years*
R. de Gaye

Dowty Electronics has designed controls for aircraft since 1948. A brief history was given with detailed examples from four systems — the Concorde Olympus 593 engine, the RB211 engine speed limiter for the Boeing 747, the BAe wing flaps controller, and RB211 engine bleed valve controller for the Boeing 757. Each of these systems contains BIT, however, since they were for commercial clients, there is little feedback on the effectiveness of the BIT.

Session II — Avionics Hardware Design for Testability
ICA C.Moreau, Chairman

9. *Built-In-Test for First Line Testing*
Geier and W.Behm

The Tornado aircraft had a requirement of 80% defects located and corrected. This specification was passed on to suppliers to implement, however, they desired both analog and digital systems. After 60,000 hours, it has been found that there is a much higher false alarm rate than desired, especially in the avionics, which has the most BIT. It appears from studies of earlier systems that 80% was too high a number and that 60% defects located and corrected would be more realistic. They feel that the problems are due to a priority conflict between performance and testability. In addition, a problem exists with the BIT reporting methods, and the lack of tests for the BIT itself. One should study the life cycle costs to determine if savings during operation will offset the costs in design and production to include BIT and DFT.

11. *Functional Built-In-Test in a Pipelined Image Processor*
H.A. van Ingen Schenau, A.Pleijsier, and A.Monkel

A pipelined image processor is described which can use predefined test patterns for functional testing. There is no automatic inspection of the test patterns.

12. *Built-In-Test and Self Repair Mechanisms in a Digital Correlator Integrated Circuit,*
W.S.Blackley, M.A.Jack, and J.R.Jordan

BIT and self repair have been included in a VLSI digital correlator for yield enhancement. The design is a modular bit-serial with near neighbor communications, cascadable, and with a clock rate of 4 MHz. Very little additional design or silicon was needed to implement the BIT. A yield enhancement factor of 9 was obtained for the first 130 chips.

Session III — Experience with Avionics Software Maintainability
W.Kuny, Chairman

15. *Maintainability — an ILS Effort to Manipulate Life Cycle Costs*
M.Boehm

Maintainability would be increased with an increase in dialogue between contractors and the military. The real issue is to decrease the life cycle costs. Most of the decisions affecting this are made early in the design phase, while most of the costs (70%) are in the maintenance phase. This dialogue is called Rüstungsrahmenerlass in Germany and has been formally set up for all phases of the life cycle.

16. *The Production of Maintainable, Trustworthy, and Portable Software*
E.S.Lee and R.C.Holt

A structured approach to design was presented. This included the user requirements specification, test requirements specification, function specification, detail design document, coding, and test and acceptance. The development of concurrent Euclid was also discussed.

17. *Documentation and Separate Test Program Development is Most Important for Test/Maintenance*
B.Güsmann and N.Sandner

Software development requires discipline, control, methods, and tools. They have a handbook of standards. They have implemented a configuration management system on UNIX, based on SCCS. Only the project manager has ownership of the files. Modules may be checked out for modification. They must pass the software control board before being checked in again. A global reference system flags all other modules referencing the changed module. For the LTR81 system, after two years and more than 50,000 flight hours, no software or mechanization errors have been found.

18. *Effective Life Cycle Software Support*
G.H.Smith

The US Navy's Pacific Missile Test Center has set up a very rigid structure for software support activity (SSA). A SSA

team is set up for each system, and must follow explicit guidelines.

19. *Experience in Using On-Aircraft Software For Testing Integrated Systems*
K.Numberger

The software used for testing the Tornado has two separate programs. One runs in flight and is resident with the operational operating system. It uses hexidecimal code output. The other software must be installed on the ground and has language coded messages. The German Air Force has found the in-flight tests good for extending the BIT (Go-NoGo) capability. The ground tests have been found to be useful as an overview of the equipment status and interface links; however, it is lengthy to run. It is felt that with increased memory capacity in the future, similar ground tests will not be needed.

Session IV — Avionics Software Design for Maintainability
L.Crovella, Chairman

20. *Software Testing in an Ada Programming Environment*
R.Taylor

Techniques for static and dynamic analysis of software were discussed. New techniques must be used for concurrent languages such as Ada. Debugging in a host-target environment is important for embedded systems. Several environments have been developed to aid the software designer.

21. *Investigating Version Dependence in Fault-Tolerant Software*
R.K.Scott, J.W.Gault, D.F.McAllister, J.Wiggs

Reliability models are needed for fault tolerant software. Data domain models for N-Version, recovery block, and concensus recovery block approaches are proposed. An experiment was performed which verified that a dependent form of the model for the recovery block could predict reliability. The dependency was thought to come from algorithmic similarities and a difficulty class.

22. *The Effect on Software Design of Testing by Symbolic Execution*
D.A.Rutherford

Symbolic execution can be used to validate a system. The cost should be reduced because no test specifications are needed, fewer documents required, fewer tests needed to provide wide coverage, and more errors found. Problems remain in the area of high-level languages, block structures, accuracy of timing tests, range of interpreters needed, and limiting the number of branch paths.

23. *Reliable Software Design for Avionics and Space Applications*
G.Giannini and P.Donzelli

Current limitations indicate that spaceborne software is written in assembler languages. Low power, small memories, and high reliability are required. LABEN has developed a software design methodology to aid in the development of such software.

13. *Design of Self-Checking N-MOS (H-MOS) Integrated Circuits*
M.Nicolaidis and B.Courtois

On-line mission and off-line after mission self-checking techniques are described for NMOS chips. Very detailed studies of precise faults are described and methods indicated for the self checking. Specific checkers are detailed.

25. *A Weapon System Design Approach to Diagnostics*
G.W.Neumann

Many techniques exist for design and maintenance of weapons systems. These are being incorporated into an integrated diagnostic package to maximize the effectiveness of the individual techniques. Very aggressive goals are expected from this integration and demonstrations are currently under way.

Session V — Future Avionics Maintainability Through Hardware/Software Co-Design
D.Franke, Chairman

The previous sessions centered on the problems and possible solutions for maintaining avionics hardware and software. The final session looked at long-term solutions, including the co-design of hardware and software.

26. *Hardware/Software Co-Design for Maintainable Systems*
G.A.Frank and D.A.Franke

Software/hardware co-design can be used to reduce the life cycle costs in all phases of the system. It can also increase maintainability. RTI has developed a methodology for co-design and is writing the ADAS (Architectural Design and Assessment System) to implement the methodology.

27. *Data Simulated On-line Checking (IROLED),*
    M.Trautwein

Residue coding techniques are used for a microprogrammable processor using IROLED (Inverse Residue code On-Line Error Detection). Estimates of the space and time overheads are given.

28. *Avionics Fault Tree Analysis and Artificial Intelligence for Future Aircraft Maintenance*
    M.E.Harris

Expert and knowledge based systems can be used to implement a microprocessor based test system. This is currently suitcase sized and will be installed on board aircraft this year. With the system on board, CND faults should be eliminated. This can lead to a two-level maintenance program.

29. *Automatic Error Detection and Recovery Techniques in On-Board Intelligent Units for Space and Avionics Application*
    R.Ranieri and R.Redaelli

Both safety and fault tolerance are necessary in space borne systems with high autonomy. Techniques used for this which incorporate both hardware and software are given.

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14. Abstract

This Technical Evaluation Report, based on the AGARD Avionics Panel Symposium on Design for Tactical Avionics Maintainability, summarizes the 25 papers presented and draws conclusions. The Conference Proceedings for this Symposium is contained in AGARD-CP-361.

The objective of this Symposium was to present, for review and discussion, advanced methods and tools to support design for avionic maintainability. Since modern avionic systems consist of programmable processors, both hardware and software design for maintainability issues and approaches were discussed.

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